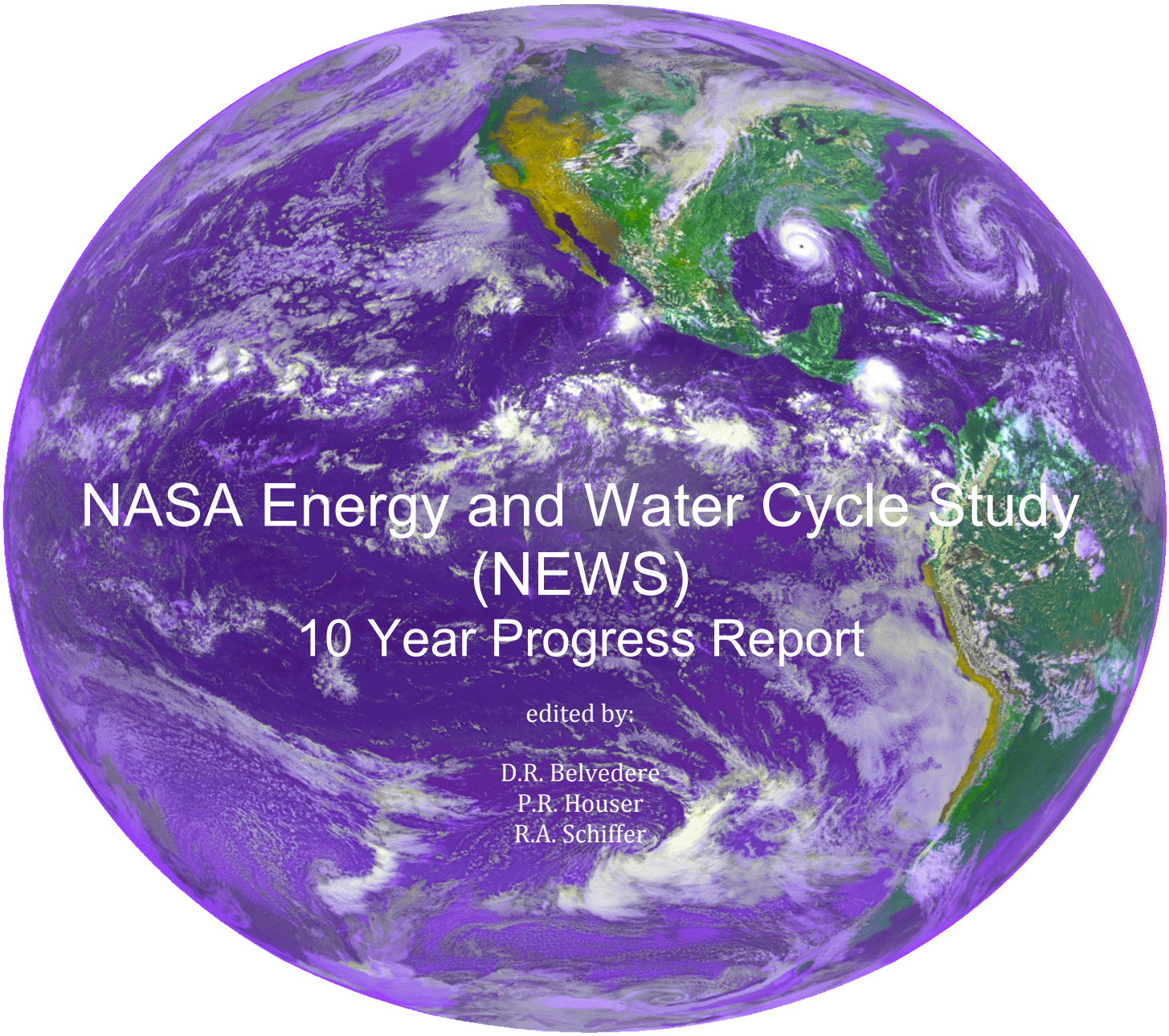

NASA Energy and Water Cycle Study (NEWS)

10 Year Progress Report

edited by:

D.R. Belvedere
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20 June 2014

Introduction/Summary

In 2003 NASA established the NASA Energy and Water Cycle Study (NEWS), whose long-term grand challenge is ***to document and enable improved, observationally based, predictions of water and energy cycle consequences of Earth system variability and change***. The NEWS program builds upon existing NASA supported basic research in atmospheric physics and dynamics, radiation, climate modeling, and terrestrial hydrology. While these NASA programs fund research activities that address individual aspects of the global energy and water cycles, they are not specifically designed to generate a coordinated result. The implementation concept for NEWS is specifically intended to promote innovative mechanisms to work across these programmatic and disciplinary boundaries.

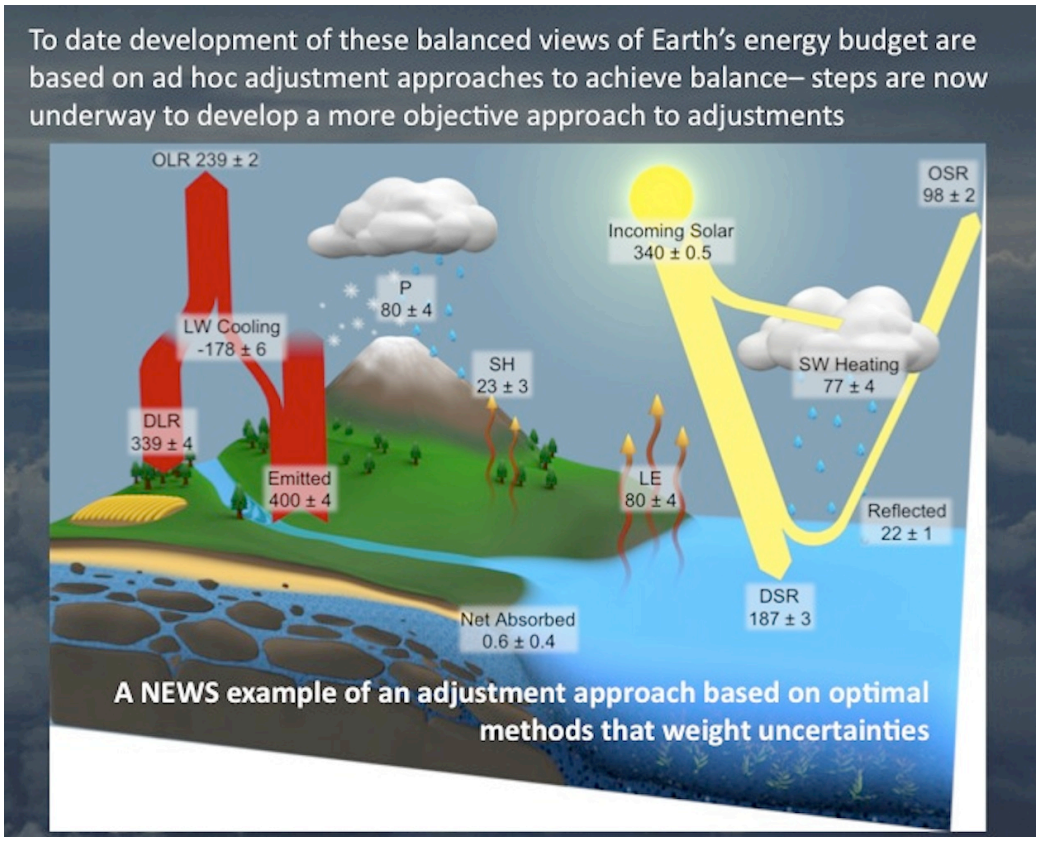
The cycling of energy and water has obvious and significant implications for the health and prosperity of society. The availability and quantity of water is vital to life on earth and helps to tie together the Earth's lands, oceans and atmosphere into an integrated physical system. The NASA Energy and Water cycle Study (NEWS) aims to:

- Derive satellite-based energy and water cycle climatologies, including monthly, continental and oceanic averages of the Earth's radiation balance, as well as precipitation, evaporation, and water vapor.
- Evaluate uncertainties to add a believability measure for application for this data and help guide future satellite technology decisions. The new integrated global water and energy assessment will be used in conjunction with NASA's Modern Era Retrospective Analysis for Research and Applications (MERRA) reanalysis, to study and improve predictions of weather and climate variability. These integrated water and energy satellite studies will provided insights to the mechanisms and severity of mid-western U.S. floods and droughts, which will help mitigate future damage caused by these extremes.
- Benefit from NASA-sponsored research using satellite observations to improve or create new estimates of water cycle variables, both fluxes and reservoirs, including their relationship with other important environmental processes. MODIS data from the Terra and Aqua satellites has been used in multiple ways to better understand snow and in-land water dynamics, especially the climate change affected regions of the northern latitudes. Additional satellite data from Aqua (AMSR-E instrument) and QuikScat have been combined with MODIS to better assess snow melt timing and dynamics. Multiple satellite data streams and hydrologic models have been used to better understand agriculture areas and drought dynamics. Satellite data has also been used to better understand and estimate the movement of water in the atmosphere, with some particular emphasis on the water flux from the world's oceans. In many cases these advances represent a strong contribution towards improving climate model representation of water cycle attributes

NEWS integrates NASA results into a state-of-the-art synthesis of the global water and energy cycles. As a team, we are the group that is looking across the NASA satellite missions to see if together, the picture that emerges is consistent/makes sense; and has allowed us to learn new things about how the planet (and the human population) moves water and energy around, including how the water cycle is accelerating.

NEWS initially focused on the first coordinated attempt to describe the complete global energy and water cycle using existing and forthcoming satellite and ground based observations, and laying the foundation for essential NEWS developments in model representations of atmospheric energy and water exchange processes. Data analysis exploits crucial datasets, some requiring complete re-processing, and new satellite measurements. These data products were evaluated for accuracy and

consistency, in part by using them in the first diagnosis of the weather-scale (space and time) variations of the global energy and water cycle over the past one-two decades. The primary objective is to ensure that results of this analysis effort serve as a recognized data basis to compare with corresponding climate statistics produced by existing climate models, quantify systematic deficiencies, and identify needed improvements. The data records to be produced through these efforts are mandatory for developing and validating models that meet NEWS scientific requirements.



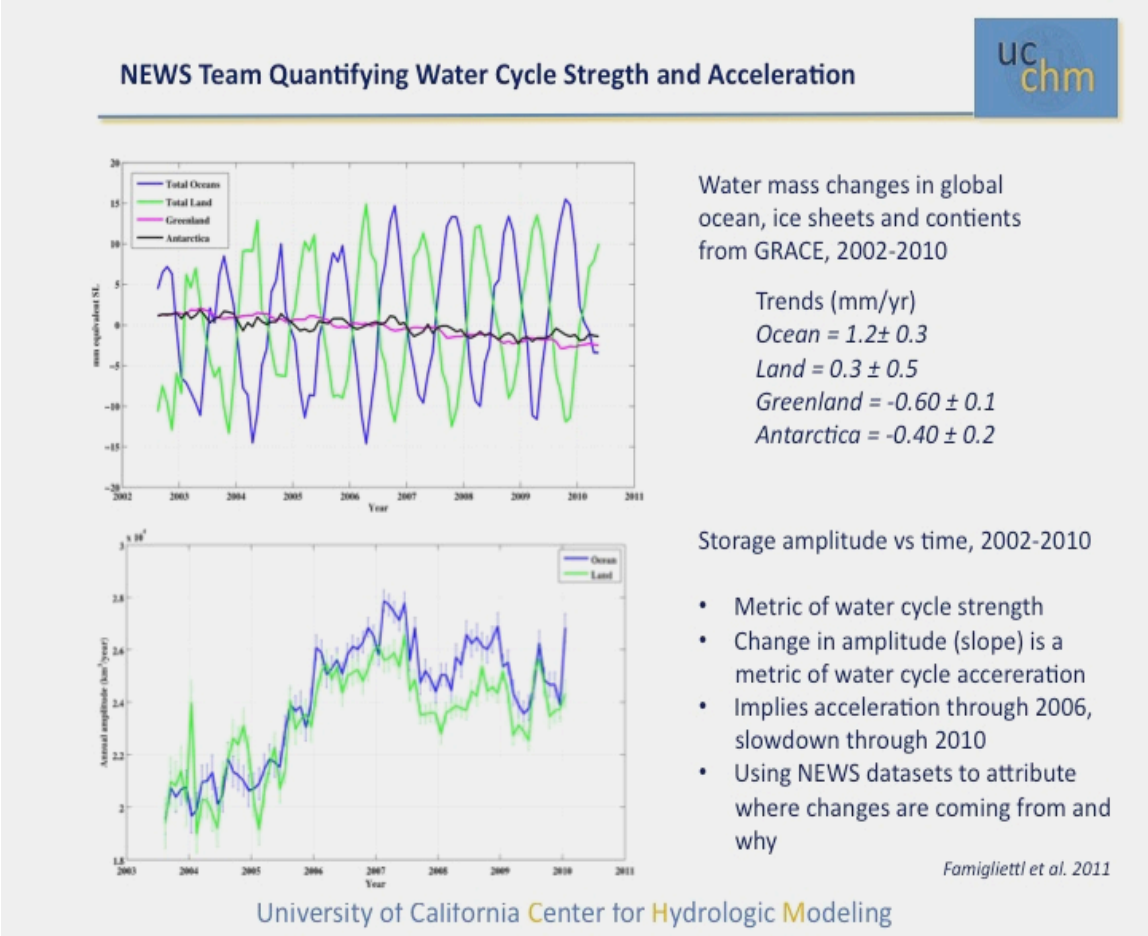
Rodell, L'Ecuyer & Team

NEWS supported research also provides the first independent assessment of the range (or uncertainty) in global ET estimates from remote sensing-driven models where the models were driven by common forcing data, based on EOS AQUA and TERRA sensor (MODIS, AIRS, CERES) data.

At the same time, NEWS has fostered the development of radically new model representations of energy and water exchange processes that resolve significant process scales and spatial variability in ground boundary conditions. Such process-resolving models may be first constructed as independent stand-alone modules that can be tested against ad hoc field measurements and systematic observations at selected experimental sites. The codes may be simplified through statistical sampling of process-scale variables or otherwise reduced to generate integrated fluxes representative of each grid-element in a climate model. This is supported by a broad exploration of potential new observing techniques concerning all aspects of the energy and water cycle, and initiating relevant technical feasibility and scientific benefit studies.

Over the past several years, the NEWS team has been working on how to refine its approach to science integration. To this end, NEWS has created working groups that identify integration needs and make the needed connections to partner and coordinate with water & energy cycle research and application activities going on at other organizations within NASA, nationally, and internationally.

NEWS has produced a lot of very good results from individual PIs, but the big payoff has been the major integrated science results resulting from collaborations or teams within NEWS. For example, the NEWS Climatology Working Group, involving about 20 NEWS PIs and Co-Is involves integrating numerous satellite data sets to estimate the global and continental-scale means and variations of both the water and energy cycles. All fields have associated errors attached and these are used to adjust the fields to achieve balance, if appropriate. This activity is unique. Individual instrument science teams do algorithms and analyze results from their instrument, MEASURES produces CDRs, IDS does non-global studies of important interdisciplinary processes. But the NEWS activity is attempting to integrate all our (primarily satellite-based) observations into a complete picture of the energy and water cycles—not just the means, but also seasonal and inter-annual variations and trends—and using the water/energy cycle conservation equations as an additional constraint. This is a big undertaking and requires significant resources over a sustained period. It obviously also has big payoffs in understanding, setting a standard for comparison with models and even in contributing to the agenda for future measurements and missions. Where are the biggest errors and uncertainties in the cycles—precipitation, soil moisture, evaporation, horizontal transport, runoff, etc.? How do we reduce the uncertainties, what observations are necessary, and what missions will deliver those improved observations. These questions and answers are at the heart of NEWS.



This integration of global water and energy observations is a unique contribution of NEWS. A good start has been made, but a strong, continuous program is important to keep all these PIs working

together toward a common goal, a goal that is much bigger than individual PI research. In addition to the climatology activity, NEWS has also made substantial integrative progress on water and energy cycle modeling, variability and extremes, latent heat fluxes, and cloud-radiation processes. This kind of integrated science is uniquely challenging, and is critical to the NASA Earth science mission, and complements other areas of Earth Science, e.g., instrument science teams, MEASURES, IDS, etc

Justification and Priorities for NEWS:

The scientific framework for the *Water and Energy Cycle focus area* is outlined in the NASA Earth Science Enterprise Strategy document, issued in October 2003. It is one of six focus areas that define the scientific content of the NASA Earth Science Program, and includes both research and technology components.

Its implementation is planned through NEWS a coordinated research program, whose central goal is "*to document and enable improved, observationally-based, predictions of energy and water cycle consequences of Earth system variability and change."*

The scientific priorities adopted by NEWS reflect the issues outlined in the Strategic Plan for the U.S. Climate Change Science Program (July 2003). These are:

- To understand the mechanisms and processes responsible for the maintenance and variability of the energy and water cycle, including the extent of human interaction
- To determine how feedback processes control the interactions between the global energy and water cycle and other components of the climate system, and how these feedbacks are changing over time
- To assess the key uncertainties in seasonal-to-annual and longer term predictions of energy and water cycle variables, and to outline improvements needed in global and regional models to reduce these uncertainties
- To evaluate the consequences, over a range of space and time scales, of energy and water cycle variability and change to human societies and ecosystems, and their affect on nutrient and biogeochemical cycles
- To provide a scientific basis for supporting informed decision processes in the context of changing water resource conditions and policies

As fully implemented, the NEWS research program is intended to yield significant advances and breakthroughs in hydrological cycle climate science. Progress in achieving its objectives is measured against its success in identifying gaps and making significant advances in:

- Promoting the development and deployment of an experimental energy and water cycle global observing system
- Assessing the global energy and water cycle through an observational record of all associated geophysical parameters
- Building a fully interactive experimental global climate model that encompasses the process-level forcings on and feedbacks within the global energy and water cycle

- Creating a global land and atmosphere data assimilation system for energy and water variables
- Assessing the variability of the global energy and water cycle on time scales ranging from seasonal to decadal, and space scales ranging from regional to continental to global
- Supporting the application of climate prediction capabilities for estimating the societal impact of climate variability and climate changes on water resources over a variety of spatial and temporal scales.

Second-tier NEWS research questions adopted were:

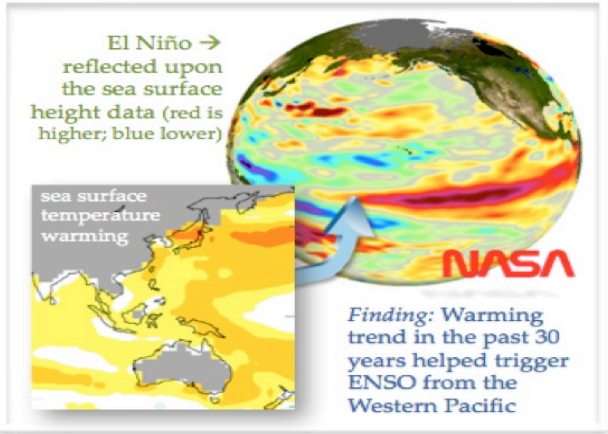
- How are global precipitation, evaporation and the cycling of water changing?
- What are the effects of clouds and surface hydrologic processes on Earth's climate?
- How are variations in local weather, precipitation and water resources related to global climate variation?
- What are the consequences of land cover and land use change for human societies and the sustainability of ecosystems?
- What are the consequences of climate change and increased human activities for coastal regions?
- How can weather forecast duration and reliability be improved?
- How can predictions of climate variability and change be improved?
- How will water cycle dynamics change in the future?

Are Greenhouse Gases Changing ENSO Precursors in the Western North Pacific?

(PI: S. Y. Wang)

The El Niño--Southern Oscillation (ENSO) has more widespread global impacts than any other climate variability. ENSO forecasts are crucial to millions of people across the world and are used by planners in agriculture, insurance, government, disaster planning, disease control, etc. to help mitigate the impact of climate extremes. Despite decades of progress, forecasting ENSO events beyond several months is still challenging.

A recent study by Wang et. al. (Sept. 2013) has identified a new ENSO precursor pattern in the Western North Pacific (WNP), whose influence appears to be strengthening in recent decades. Since the mid-20th century, the WNP pattern has become more strongly linked to ENSO development. Modeling analysis suggests that greenhouse gas forcing is largely responsible for such a strengthened relationship between the WNP pattern and ENSO development. These results suggest increased confidence in climate predictions during the coming decades.



Wang, Shih-Yu, Michelle L'Heureux, Jin-Ho Yoon, 2013: Are Greenhouse Gases Changing ENSO Precursors in the Western North Pacific? *J. Climate, 26,* 6309–6322.doi: http://dx.doi.org/10.1175/JCLI-D-12-00360.1 (Sept 2013)

The broad national objectives of energy and water related climate research extend well beyond the purview of any single agency or program, and call for the support of many activities that are matched to each agency's respective roles and missions. NASA has the experience and expertise to support the full range of investigations, from global-remote sensing to point-scale field observations, global data acquisition, and the development of prediction systems that can assimilate these measurements.

Therefore, to achieve the ultimate goal of operational global change predictions and applications across all significant scales NASA will seek collaborations with other Federal agencies, in particular the National Oceanic and Atmospheric Administration (NOAA), National Science Foundation (NSF), Department of Energy (DoE), U.S. Geological Survey (USGS), Department of the Interior (DoI), the Department of Agriculture (DoA), the scientific community-at-large and private industry. Such interagency collaborations, reflect NASA contributions to the overall Climate Change Science Program (CCSP) Global Water Cycle (GWC) initiative, and include experimental and operational observations and analysis tools for characterizing air/sea fluxes, ocean circulation, atmospheric state, land surface vegetation, sub-surface hydrology, snow and ice among others; as well as support for the development of new general circulation models and end-to-end prediction systems. In some cases, NASA investments may be required to supplement these activities to ensure that they meet specific needs, for example, *in situ* measurements of parameters that are essential to validating space based remote sensing, as well as quantities needed but not otherwise measured or derived.

The NEWS research linkage to the international science community is primarily through the World Climate Research Programme (WCRP), especially the Global Energy and Water Experiment (GEWEX), but includes several complementary elements of Climate Variability and Predictability (CLIVAR) and Climate and Cryosphere (CLIC). GEWEX has overall WCRP responsibility for providing an international interface with all the national space agencies concerning energy and water cycle related global climate research requirements, instruments, data, and science support. Other international connections include those with the International Geosphere-Biosphere Program (IGBP) and the International Human Dimensions Program (IHDP)

Brief History:

Implementation of the NEWS program was initially planned in three phases, each successive phase being focused on a range of research activities, as described in the NEWS Implementation Plan, and represents advances beyond the current status of observations, modeling and applications. The next-generation prediction system will be based on a global observing and assimilation system to determine the initial state of climate (especially external and internal forcings) and a modeling system to make the forecast, neither of which currently exist in complete or accurate form. Developing the prediction capability requires progressing through a iterative cycle of research elements: observations, analysis, model development and testing, evaluation, and demonstration of applications. The development of observing/data analysis system capabilities evolves in parallel with the program's research efforts to further develop prediction models and applications.

The emphasis during Phase-1 is to exploit current capabilities and prepare for future developments of NEWS program elements. Phase-2 focuses on addressing deficiencies and building a viable "prediction" system. Phase-3, focuses on the delivery of an end-to-end system to address the NASA Earth Science vision, namely: comprehensive observations to accurately quantify the state and variability of the global water cycle, including time series data sets with no major gaps; routine analysis of variability in storage, transports and fluxes of water ; routine prediction of key water cycle parameters (including clouds, precipitation, radiation interactions, energy budgets, and surface hydrological variables), and improved forecasts for use in water management and decision making.

Specifically, the first phase focuses on the first coordinated attempt to describe the complete global energy and water cycle using existing and forthcoming satellite and ground based observations, and laying the foundation for essential NEWS developments in model representations of atmospheric energy and water exchange processes. This comprehensive energy and water data analysis program must exploit crucial datasets, some still requiring complete re-processing, and new satellite measurements. These data products will then be evaluated for accuracy and consistency, in part by using them in the first diagnosis of the weather-scale (space and time) variations of the global energy and water cycle over the past one-two decades. The primary objective is to ensure that results of this analysis effort serve as a recognized data basis to compare with corresponding climate statistics produced by existing climate models, quantify systematic deficiencies, and identify needed improvements. The data records to be produced through these efforts are mandatory for developing and validating models that meet NEWS scientific requirements.

The second phase will focus on correcting the deficiencies identified in the first phase, exploiting and evaluating the newer measurements from recently deployed satellites (especially GPM), advancing multivariate analysis procedures to exploit the full range of observations, and developing new measurement approaches for future flight missions. Simultaneously, the second phase includes implementing new process-resolving or otherwise improved representations of energy and water exchange processes in general circulation models (GCM), assembling a complete end-to-end data assimilation and prediction system for seasonal and shorter-range forecasts, and testing the predictions against observed transient variations or changes in climate statistics. This will involve reprocessing of legacy data as required. An important objective of the second phase is to deliver useful seasonal predictions that can be applied to, and evaluated for their value to optimize water management decision-making.

The third phase will focus on facilitating the development of a capability for short term, and annual to decadal-scale climate predictions, in cooperation with the climate modeling community. The implementation plan calls for delivery of advanced atmospheric GCM formulations that can demonstrably predict changes in the energy and water cycle up to at least several seasons. An objective of the third phase will be testing against observations decadal predictions produced by fully interactive models of the complete climate system and/or simpler configurations involving the partial replacement of active components by observed boundary conditions. The third phase will also aim to deliver more penetrating tests of model performances using extended analyses of the widest possible range of observations, including some of the new global observing systems evaluated in the second phase.

It was envisioned that the NEWS program will build upon existing NASA-supported basic research in atmospheric physics and dynamics, radiation, climate modeling, and terrestrial hydrology. While these NASA programs fund research activities that address individual aspects of the global energy and water cycles, they are not specifically designed to generate a coordinated result. The implementation concept for NEWS is specifically intended to promote innovative mechanisms to work across these programmatic boundaries. Based on the NEWS Implementation Plan central issue of assessing the key uncertainties in seasonal-to-annual and longer-term energy and water cycle predictions, and outline model improvements needed to reduce these uncertainties, the following milestones were adopted for each NEWS phase.

Phase 1

• Improve current parameterizations of clouds and precipitation, land surface hydrology, atmospheric boundary layer and ocean mixed layer

• Develop stand-alone ultra-high resolution cloud process and land hydrology models with atmospheric coupling for water/energy fluxes, soil moisture, runoff

• Develop high resolution models for coupled clouds, radiation and hydrology

• Test embedded process models in general circulation models

• Develop and test advanced energy and water data assimilation methods

• Quantify/evaluate causes/differences in precipitation predictions between global precipitation prediction models

• Establish performance metrics for energy and water predictions

Phase 2

• Develop simplified process resolving representations of precipitation and land hydrology for GCM simulations

• Evaluate conventional parametric representations of clouds, precipitation, boundary layer, land hydrology in climate models compared with weather events and observed seasonal/interannual variations

• Assess similarities and differences between model climate variability on short time scales and forced responses of models on longer time scales

• Improve representation of slow feedback processes

• Determine most informative model products for predicting water supply

• Assemble experimental end-to-end energy and water cycle prediction system from observations to data assimilation, model initialization and prediction, to assessments of hydrological consequences and decision support systems

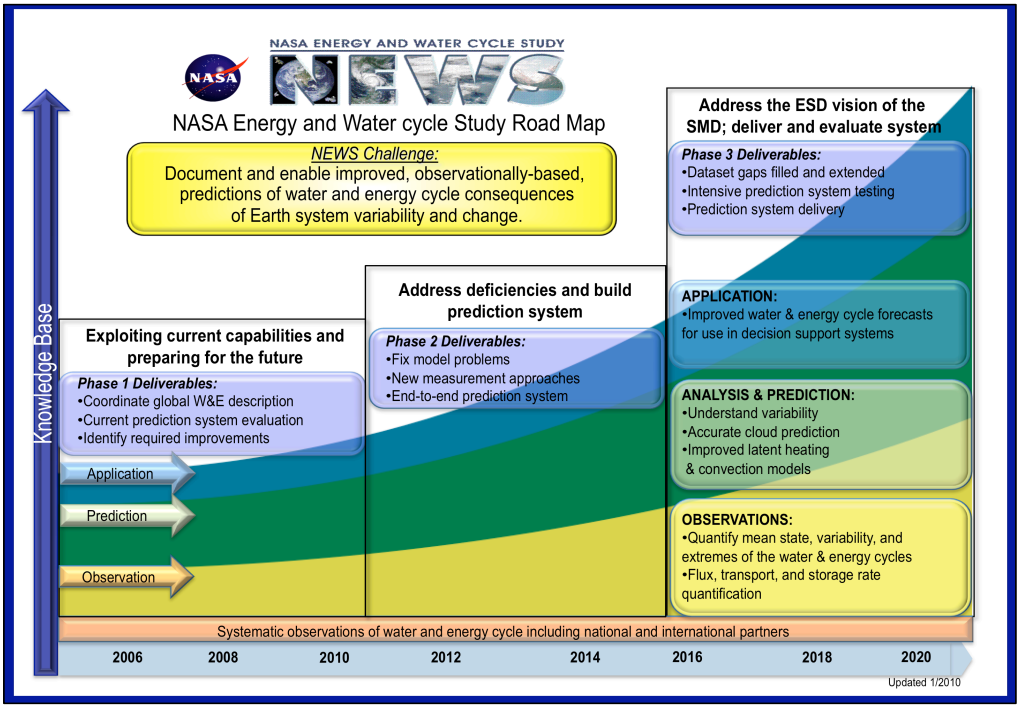
Phase 3

• Produce a fully interactive global climate system model that characterizes the complete energy and water cycle

• Construct a comprehensive energy and water data assimilation and prediction system

• Conduct a full end-to-end test of the prediction system against the past 30 to 50 year observational record

The overall planning strategy is reflected in the NEWS roadmap (updated 1/20/10).



Evolving Organizational Structure and Implementation:

From 2003 to 2009, the NEWS activity was initially comprised principally of product-driven investigations, discovery exploration-driven investigations and integrative efforts studies.

Product-Driven Investigations: Systematic research investigations intended to combine and interpret past and current observations, derive global analysis and prediction tools and products and identify technological and observational requirements to guide future NASA investments.

Discovery-Driven Investigations: Fundamental investigations to identify key missing elements and explore new scientific frontiers to improve capabilities and knowledge of the energy and water components of the Earth system..

NEWS Science Integration Team (NSIT): Integration of the science activities to serve the overall purpose of NASA by acting as an interface with other Earth Science research foci and activities, coordinating the conduct of NEWS investigations, and leading specific studies needed for integration of the results of independent product-driven or discovery-driven investigations.

NSIT membership: Entin (NASA Hq), Houser (GMU), Schiffer (UMBC), Rossow (GISS), Schlosser (MIT), Lapenta (MSFC), Lin (LaRC), Njoku (JPL), Belvedere (CREW)

NEWS Principal Investigators (2003): Alan Betts (Atmospheric Research), William Olson (NASA/GSFC), Robert Adler (NASA/GSFC), Brian Soden (Univ. of Miami, CIMAS), Bruce Wielicki (NASA/Langley), Christa Peters-Lidard (NASA/GSFC, Eric Fetzer (JPL), Frank Wentz (Remote Sensing Systems, Jay Famiglietti (UCI, John Roads (Scripps Inst. of Oceanography), Judith Curry (Georgia Tech), Matthew Rodell (NASA/GSFC), Michael Bosilovich (NASA/GSFC), Randall Koster (NASA/GSFC), Ruby Leung (Battelle PNNL), Scott Denning (CSU), Siegfried Schubert (NASA/GSFC), Soroosh Sorooshian (UCI), Timothy Liu (JPL), Tristan L'Ecuyer (CSU), Dennis Lettenmaier (UWA), Xiquan Dong (UND), Yongxiang Hu (NASA/Langley), Sally McFarlane (PNNL), Duane Waliser (JPL)

Exchanges of energy and water within the Earth system involve a multiplicity of interactive processes. Understanding and predicting these processes require a complex multi-disciplinary research program, innovative observing tools, and advanced model developments. Organizing these complex activities calls for dedicated management and oversight approaches to ensure that both financial and human resources are efficiently applied to serve NASA Earth Science priorities.

In 2007 emphasis was placed on adopting a set of Science Integration Themes to exploit the diverse expertise of the broad NEWS community in addressing important cross-cutting issues essential to achieving overall program success. These themes focused on:

- Improving understanding and description of the physical processes and feedbacks which control the role of energy and water cycles and their influence on global climate variability and change.

NEWS Investigators: Famiglietti, Betts, Roads, Liu, L'Ecuyer, Adler, Curry, Peters-Lidard

- Improving the retrieval and validation methodologies for deriving energy and water cycle parameters from remote sensing observations.

NEWS Investigators: Olson, Wentz, Fetzer, Wielicki, Dong, McFarlane

- Improving modeling and data assimilation techniques for evaluating and predicting hydro-meteorological elements of the global climate system on seasonal and longer time scales.

NEWS Investigators: Koster, Denning, Soden, Bosilovich, Rodell, Hu, Waliser

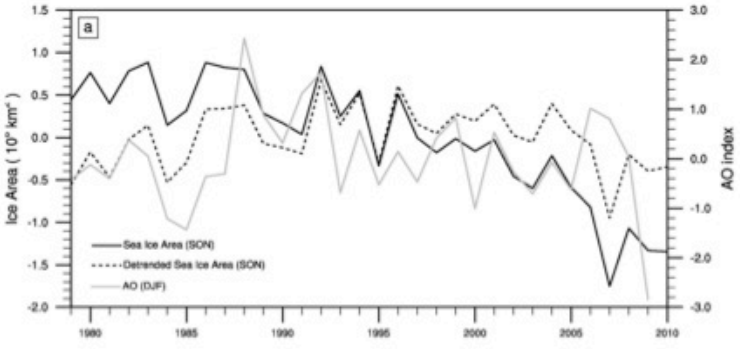
- Testing and demonstrating the value of energy and water cycle data products, diagnostics, and prediction capabilities to meet the needs of regional and national applications oriented problems.

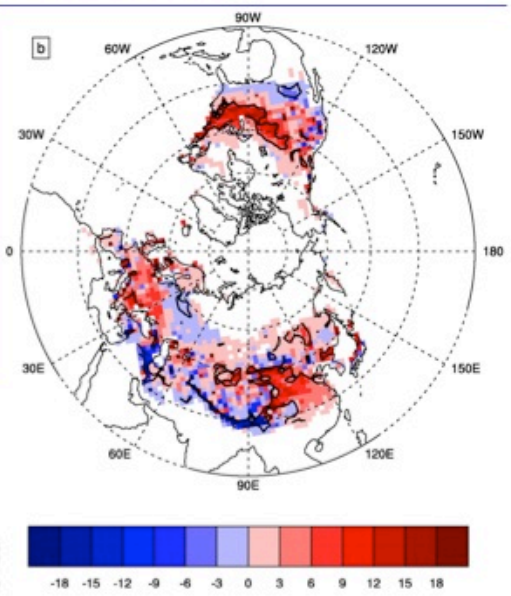
NEWS Investigators: Leung, Schubert, Sorooshian, Lettenmaier

Impact of Declining Arctic Sea Ice on Winter Snowfall

Jiping Liu and Judith Curry, Georgia Institute of Technology

Analysis of satellite data sets of sea ice and snow cover in combination with atmospheric circulation data demonstrates that the anomalous increase in NH winter snow extent is linked to changes in the winter NH atmospheric circulation that are in turn linked to decreased autumnal extent of Arctic sea ice. This circulation change results in more frequent episodes of blocking patterns that leads to increased cold surges over large parts of northern continents. The increase in atmospheric water vapor content in the Arctic region during late autumn and winter in response to the reduction of sea ice provides enhanced local moisture sources, supporting increased heavy snowfall in Europe and northeastern and mid-west U.S.





linear regression of winter snow cover anomalies (%) on the detrended autumn Arctic sea ice area anomaly

July 2011

Curry et.al

Since initiation of the project by NASA and publication of the Science Implementation Plan in 2007, NEWS has focused on addressing the range of its Phase 1 objectives. The first phase focuses on the first coordinated attempt to describe the complete global energy and water cycle using existing and forthcoming satellite and ground based observations, and laying the foundation for essential NEWS developments in model representations of atmospheric energy and water exchange processes. This comprehensive energy and water data analysis program must exploit crucial datasets, some still requiring complete re-processing, and new satellite measurements. These data products will then be evaluated for accuracy and consistency, in part by using them in the first diagnosis of the weather-scale (space and time) variations of the global energy and water cycle over the past one-two decades. The primary objective is to ensure that results of this analysis effort serve as a recognized data base to compare with corresponding climate statistics produced by existing climate models, quantify systematic deficiencies, and identify needed improvements. The data records to be produced through these efforts are mandatory for developing and validating models that meet NEWS scientific requirements.

At the same time, this implementation plan calls for the development of radically new model representations of energy and water exchange processes that resolve significant process scales and spatial variability in ground boundary conditions. Such process-resolving models must be first constructed as independent stand-alone modules that can be tested against *ad hoc* field measurements and systematic observations at selected experimental sites. At a later stage, the codes may be simplified through statistical sampling of process-scale variables or otherwise reduced to generate integrated fluxes representative of each grid-element in a climate model. Finally,a broad

exploration of potential new observing techniques concerning all aspects of the energy and water cycle, and initiating relevant technical feasibility and scientific benefit studies.

As of 2009, the project has been working on how to redefine the NEWS team approach to tackling integration. NEWS is attempting to create a structure that allows for consistency from existing NEWS activities, (i.e., conservation of scientific momentum), and at the same time welcomes new PIs and their projects. To these ends, the project created four NEWS working groups that identify integration needs and make the needed to partner and coordinate with water & energy cycle research and application activities going on at other organizations within NASA, nationally, and internationally. The four working groups established in 2009 were:

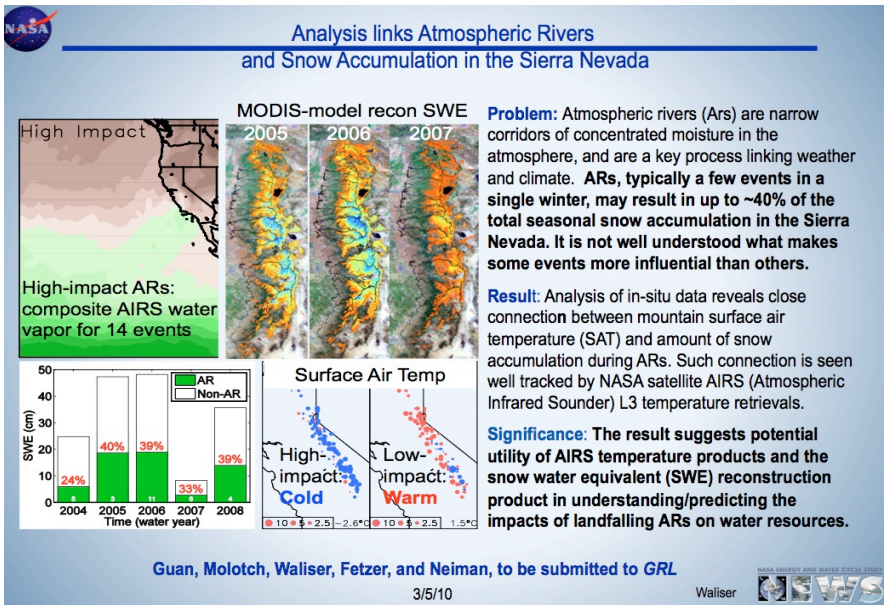
Drought & Flood Extremes - including water and energy aspects of abrupt climate change (Co-Chairs: Dong, Albertson/Deng)

Evaporation & Latent Heating - including both land and ocean (Co-Chairs: Hilburn, Famiglietti)

Water and Energy Cycle Climatology - to exploit and influence evolving observing systems (Co-Chairs: Rodell, L'Ecuyer)

Modeling & Water Cycle Prediction - foster interaction with the global modeling community (Co-Chairs: Bosilovich, Hu)

The working groups were charged with coordinating and integrating NEWS PI science investigations; liaise with relevant flight missions and NASA R&A Programs; implement annual assessment of progress in meeting NEWS scientific requirements; and contribute to periodic Implementation Plan (IP) updates. A principal goal of the working groups was to promote the development of scientific papers that integrate various NEWS research within the working group topic area. The WGs were further charged with coordinating with the NEWS investigator groups established previously in 2007 to carry out research under a set of defined themes, such as: Improving understanding and description of the physical processes and feedbacks which control the role of energy and water cycles and their influence on global climate variability and change, improving the retrieval and validation methodologies for deriving energy and water cycle parameters from remote sensing observations, improving modeling and data assimilation techniques for evaluating and predicting hydro-meteorological elements of the global climate system on seasonal and longer time scales, and, testing and demonstrating the value of energy and water cycle data products, diagnostics, and prediction capabilities to meet the needs of regional and national applications oriented problems.



Current Working Groups

The 2013 Science Team Meeting emphasized integrating the 18 new NEWS science investigations selected by NASA as a result of the ROSES-2011 solicitation. The working group structure was updated to reflect the scientific priorities of the membership, while still adhering to the basic objectives and goals of the NEWS program as established in 2003, followed by clarifications in 2007 and 2009. The new structure consists of:

Cloud and Radiation Working Group – to link clouds, precipitation, and the energy budget of the southeastern Pacific stressing the importance of boundary layer clouds to the radiative energy budget, the relationships between clouds and radiative effects, and impacts of precipitation on cloud and radiative properties

WG membership: Bennartz, Jiang, Kato, Olson, Pinker, Su, Taylor

Extremes Working Group – to focus on understanding severe drought in the United States. The 2012 drought may not have been predictable as based on current schemes employed for such purposes, but it may have been anticipatable due to knowledge of key precursors such as favorable (remote) SST patterns, and reduced regional soil moisture and winter snow packs. Thus, the plan is to examine the extent to which the 2012 drought could be anticipated and to put recent severe droughts in perspective. This theme was determined because (1) extreme events are local and require a regional focus in the analysis; (2) the members of this group have ongoing research focusing on the central U.S.; and (3) attribution of extreme events in the U.S. is under active debate and the strength of the NEW Steam can provide further clue

WG membership: Wang, Barandiaran, Hilburn, Houser, Oglesby, Pan, Pinker, Santanello, Schubert, Wang

Climate Shift Working Group – During the last 25- 30 years of satellite and re-analysis information global surface warming and increases in ocean water vapor are evident, primarily in the pre-1998 period, with a leveling off of these increases in the post-1998 period. This "climate shift" is similar to an earlier inter-decadal change event in the late 1970s and has been linked to changes in ocean-atmosphere interactions linked to Pacific Decadal Variability (PDV), although other processes (AMO, aerosols, etc.) could also be involved. There is also evidence that other components of the water (and energy) cycles show a shift at approximately the 1998-2000 point. However, not all the global data sets and re-analyses agree and/or have homogeneity issues. The WG is exploring this subject to better document and understand the "shift" and also understand the strengths and weaknesses of the global data sets and re-analyses to build a group consensus as to "what happened" and which data sets/re-analyses can be used with what level of confidence. This activity will also point to possible actions to improve the data sets and re-analyses for more confident research in the future.

WG membership: Adler, Guojun, Huffman, Robertson, Bosilovich, Lettenmaier

Evaporation and Latent Heating Working Group – to evaluate the latent heating transport from over a region (discussed below), for the NEWS time period of 1998 - 2007, in order to determine mean seasonal flux; interannual variability; (3) the statistical distribution of events. This would lead to an analysis of extremes oer other aspects of the distribution and how this relates to surface variability and atmospheric transport variability. An analysis of the extremes can then also be tied to specific weather events, such as atmospheric rivers or cyclonic events, and(4) an analysis of trends in the transport over the time period

WG membership: Clayson, Wood, Bosilovich, Cullather, Olson, Pinker, Bennartz

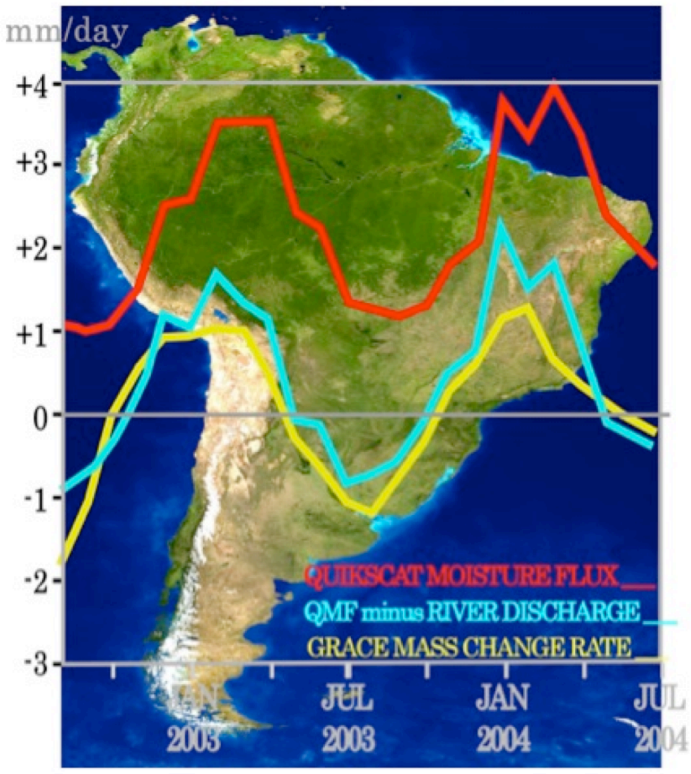
Summary and Important Accomplishments/Highlights:

The NASA Energy and Water cycle Study (NEWS) compiled the first-ever satellite-based energy and water cycle climatology, including monthly, continental and oceanic averages of the Earth's radiation balance, as well as precipitation, evaporation, and water vapor. The accompanying uncertainty evaluation adds a believability measure for application for this data and is helping to guide future satellite technology decisions. This new integrated global water and energy assessment is being used in conjunction with NASA's Modern Era Retrospective-Analysis for Research and Applications (MERRA) reanalysis, to study and improve predictions of weather and climate variability. These integrated water and energy satellite studies have also provided insights to the mechanisms and severity of mid-western U.S. floods and droughts, which will help mitigate future damage caused by these extremes.

NASA-sponsored research using satellite observations has improved or created new estimates of water cycle variables, both fluxes and reservoirs, including their relationship with other important environmental processes. MODIS data from the Terra and Aqua satellites has been used in multiple ways to better understand snow and in-land water dynamics, especially the climate change affected regions of the northern latitudes. Additional satellite data from Aqua (AMSR-E instrument) and QuikScat have been combined with MODIS to better assess snow melt timing and dynamics. Multiple satellite data streams and hydrologic models have been used to better understand agriculture areas and drought dynamics. Satellite data has also been used to better understand and estimate the movement of water in the atmosphere, with some particular emphasis on the water flux from the world's oceans. In many cases these advances represent a strong contribution towards improving climate model representation of water cycle attributes.

NEWS Multisensor Synergism - 1

Ocean Influence on Continental Water Balance



Ocean plays a dominant role over the seasonal changes of continental water balance and regional rainfall of South America, as revealed by combining the monthly rate of mass change from GRACE data, the transport of moisture across the coastline from QuikSCAT wind vector and SSM/I water vapor, rainfall by TRMM, and river discharge climatology.

Liu et al. (2006), Geophysical Research Letter

The NASA Energy and Water cycle Study (NEWS) has allowed us to integrate NASA results into a state-of-the-art synthesis of the global water and energy cycles. As a team, we are the group that is looking across the NASA satellite missions to see if together, the picture that emerges allows us to learn new things about how the planet (and the human population) moves water and energy around, including how the water cycle is accelerating.

NEWS Supported research also allows the first independent assessment of the range (or uncertainty) in global ET estimates from remote sensing-driven models where the models were driven by common forcing data, based on EOS AQUA and TERRA sensor (MODIS, AIRS, CERES) data. Continued work using 1984-2008 ISCCP and SRB radiation data sets is on-going.

At the same time, NEWS has fostered the development of radically new model representations of energy and water exchange processes that resolve significant process scales and spatial variability in ground boundary conditions. Such process-resolving models may be first constructed as independent stand-alone modules that can be tested against ad hoc field measurements and systematic observations at selected experimental sites. The codes may be simplified through statistical sampling of process-scale variables or otherwise reduced to generate integrated fluxes representative of each grid-element in a climate model. This is supported by a broad exploration of potential new observing techniques concerning all aspects of the energy and water cycle, and initiating relevant technical feasibility and scientific benefit studies.

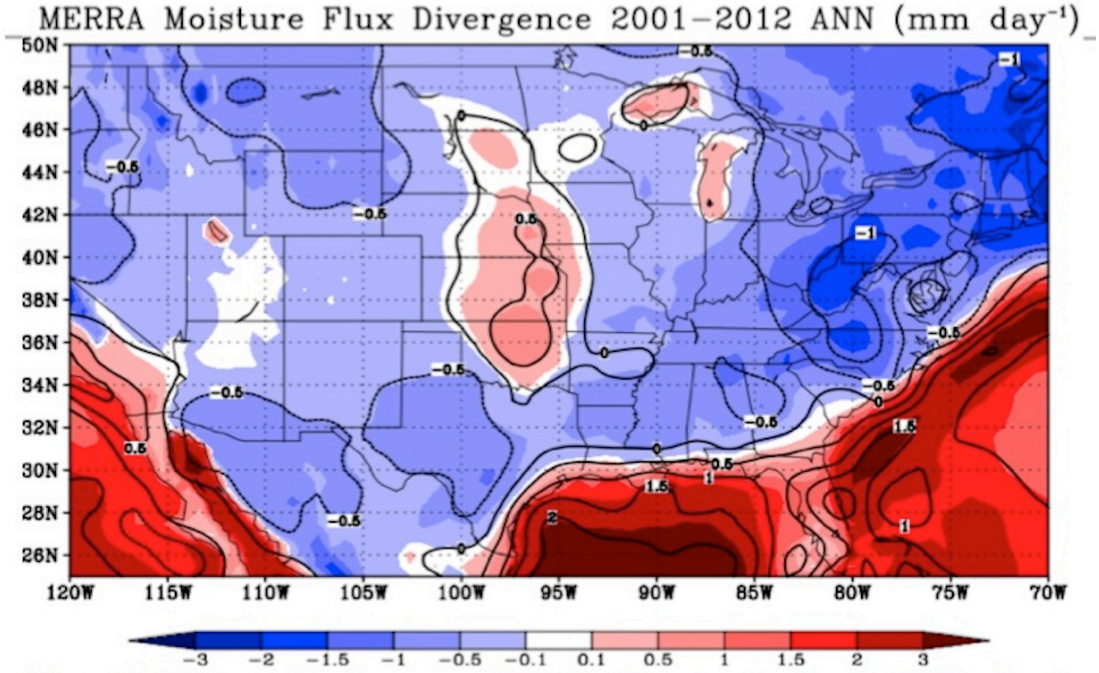


Figure 1. *Moisture flux divergence (MFD), following Trenberth (2011) showing divergence over the Central US, which implies E>P in the long term sense. Black contours show the analysis increment tendency for water vapor.*

NEWS has produced a lot of very good results from individual PIs, but the big payoff has been the major integrated science results resulting from collaborations or teams within NEWS. For example, the NEWS Climatology Working Group, involving about 20 NEWS PIs and Co-Is has taken on a very large project of integrating numerous satellite data sets to estimate the global and continental-scale means and variations of both the water and energy cycles. All fields have associated errors attached and these are used to adjust the fields to achieve balance, if appropriate. This activity alone makes NEWS

worthwhile and unique. Individual instrument science teams do algorithms and analyze results from their instrument, MEASURES produces CDRs, IDS does non-global studies of important interdisciplinary processes. But the NEWS activity is attempting to integrate all our (primarily satellite-based) observations into a complete picture of the energy and water cycles, not just the means, but also seasonal and inter-annual variations and trends—and using the water/energy cycle conservation equations as an additional constraint. This is a big undertaking and requires significant resources over a sustained period.

Selected Highlights:

Below we highlight some of the NEWS accomplishments. These highlights are based on highly cited science, media attention, as well as results identified by the NEWS team.

- Climate models and satellite observations both indicate that the total amount of water in the atmosphere will increase at a rate of 7% per kelvin of surface warming. However, the climate models predict that global precipitation will increase at a much slower rate of 1 to 3% per kelvin. A recent analysis of satellite observations does not support this prediction of a muted response of precipitation to global warming. Rather, the observations suggest that precipitation and total atmospheric water have increased at about the same rate over the past two decades.

Wentz, F. J, L Ricciardulli, K. A. Hilburn and Carl Mears, 2007: How Much More Rain will Global Warming Bring? *Science*, 317, 233-235, doi: 10.1126/1140746 (cited by 438)

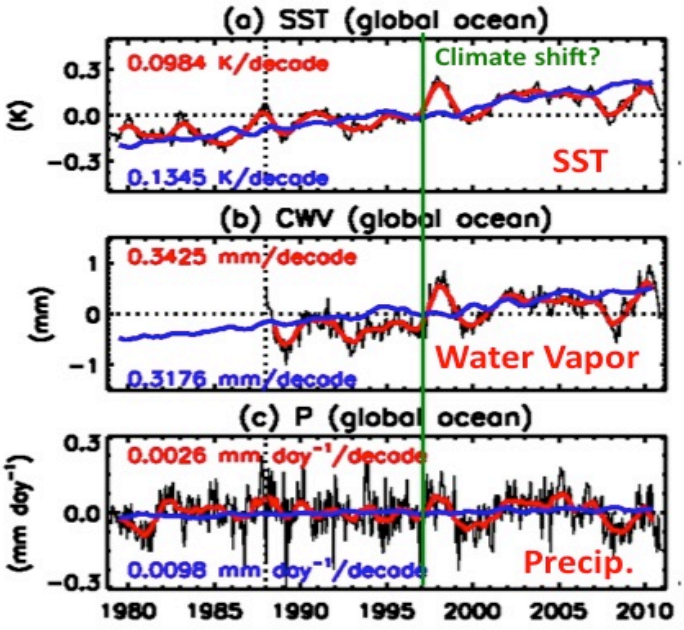
http://www.sciencemag.org/content/317/5835/233.abstract?sid=42244e1e-b5bd-4a94-afdc-c585e4384bb9.

- Global and large regional rainfall variations and possible long-term changes are examined using the 27-yr (1979–2005) Global Precipitation Climatology Project (GPCP) monthly dataset. Emphasis is placed on discriminating among variations due to ENSO, volcanic events, and possible long-term climate changes in the Tropics.

  The impact of the two volcanic eruptions is estimated to be about a 5% reduction in tropical rainfall over both land and ocean. A modified dataset (with ENSO and volcano effects removed) retains the same approximate linear change slopes, but with reduced variances, thereby increasing the statistical significance levels associated with the long-term rainfall changes in the Tropics. Increase in tropical rainfall, impact of volcanoes.

Gu, G., R. Adler, G. Huffman, and S. Curtis, 2007: Tropical Rainfall Variability on Interannual-to-Interdecadal/Longer-Time Scales Derived from the GPCP Monthly Product, *J. Climate*, 20, 4033-4046. (cited by 100) http://journals.ametsoc.org/doi/abs/10.1175/JCLI4227.1

Global Ocean Mean: surface temperature, column water vapor, and precipitation : Observed (Red) vs Model HistGHG (Blue)



- Observations clearly show *increase in SST and ocean water vapor during post 1979 era*. *Precipitation shows zero trend*. *Climate shift* can be discerned about 1998 in SST and water vapor, but not in precipitation.
- Long-term surface temperature and oceanic water vapor changes/trends are simulated by the GISS model very well, *suggesting the dominance of GHG forcing in global surface warming*.
- Inter-annual signals weak in model compared to observations.

• In 2008 Fetzer and Lin delivered a five-year (2003-2006) record of AIRS and AMSR-E water vapor, and AMSR-E cloud liquid water content. The MLS upper troposphere and middle atmosphere water vapor, and ice water content estimates are included for the period from July 2004 through the end if 2006. Co-I Bill Iron was engaged in AIRS and NLS validation activities. These activities will lead to a true merge AIRS-MLS-AMSR-E water vapor product.

Fetzer, E. J., et al. (2008), Comparison of upper tropospheric water vapor observations from the Microwave Limb Sounder and Atmospheric Infrared Sounder, *J. Geophys. Res*., 113, D22110, doi:10.1029/2008JD010000.

• The capability of a global data compilation, largely satellite based, is assessed to depict the global atmospheric water cycle's mean state and variability. Monthly global precipitation estimates from the Global Precipitation Climatology Project (GPCP) and the Climate Prediction Center (CPC) Merged Analysis of Precipitation (CMAP) span from 1979 to 1999. Monthly global Special Sensor Microwave Imager (SSM/I)-based bulk aerodynamic ocean evaporation estimates span from June 1987 to December 1999. Global terrestrial evapotranspiration rates are estimated over a multidecade period (1975–99) using a global land model simulation forced by bias-corrected reanalysis data. Monthly total precipitable water (TPW) from the NASA Global Water Vapor Project (NVAP) spans from 1988 to 1999.

The averaged annual global precipitation (P) and evaporation (E) estimates are out of balance by 5% or 24 000 (metric) gigatons (Gton) of water, which exceeds the uncertainty of global mean annual precipitation (~±1%). For any given year, the annual flux imbalance can be on the order of 10% (48 000

Gton of water). However, observed global TPW interannual variations suggest a water flux imbalance on the order of 0.01% (48 Gton of water)—a finding consistent with a general circulation model (GCM) simulation. Variations in observationally based global P and E rates show weak monthly and interannual consistency, and depending on the choice of ocean evaporation data, the mean annual cycle of global E − P can be up to 5 times larger to that of TPW. The global ocean annual evaporation rates have as much as a ~1% yr^{-1} increase during the period analyzed (1988–99), which is consistent in sign with most transient CO_2 GCM simulations, but at least an order of magnitude larger. The ocean evaporation trends are driven by trends in SSM/I-retrieved near-surface atmospheric humidity and wind speed, and the largest year-to-year changes are coincident with transitions in the SSM/I fleet.

In light of (potential) global water cycle changes in GCM projections, the ability to consistently detect or verify these changes in nature rests upon one or more of the following: quantification of global evaporation uncertainty, at least a twofold improvement in consistency between the observationally based global precipitation and evaporation variations, a two order of magnitude rectification between annual variations of E − P and precipitable water as well as substantial improvements in the consistency of their seasonal cycles, a critical reevaluation of intersatellite calibration for the relevant geophysical quantities used for ocean evaporation estimates, and the continuation of a dedicated calibration in this regard for future satellite transitions.

Schlosser, C. Adam, Paul R. Houser, 2007: Assessing a Satellite-Era Perspective of the Global Water Cycle. *J. Climate,* 20, 1316–1338.doi: http://dx.doi.org/10.1175/JCLI4057.1

- Climate models suggest that extreme precipitation events will become more common in an anthropogenically-warmed climate. However, observational limitations have hindered a direct evaluation of model-projected changes in extreme precipitation. We used satellite observations and model simulations to examine the response of tropical precipitation events to naturally driven changes in surface temperature and atmospheric moisture content. These observations reveal a distinct link between rainfall extremes and temperature, with heavy rain events increasing during warm periods and decreasing during cold periods. Furthermore, the observed amplification of rainfall extremes is found to be larger than that predicted by models, implying that projections of future changes in rainfall extremes in response to anthropogenic global warming may be underestimated.

Allan, R. P., and B. J. Soden, 2008: Atmospheric Warming and the Amplification of Precipitation Extremes. *Science*, 321 (5895), 1481-1483. (cited by 382) http://www.sciencemag.org/content/321/5895/1481.abstract

- A relationship between surface air temperature and total precipitable water vapor in historical records and AIRS observations over northern Eurasia has been established. In cold conditions total water vapor follows surface air temperature closely. During warmest conditions total water vapor increases slowly with surface air temperature.

  These results show that warmest conditions are associated with lowest relative humidity over Eurasia. This suggests that climate models may be overestimating the strength of water vapor-driven greenhouse warming at high latitudes during summer.

Ye, H., and E. J. Fetzer (2009), Atmospheric moisture content associated with surface air temperatures over northern Eurasia, Int. *J. Hydrology*, **Lead Author Hengchun Ye received the American Association of Geographers Climate Specialty Group John Russell Mather Paper of the Year Award for this study

- The potential impact of anomalous cloud cover on the 2007 Arctic sea ice minimum was established using CloudSat and CALIPSO (A-Train) data. The results suggest that reduced cloud cover in 2007 may have significantly enhanced sea ice melt. The results highlight the importance of considering potential atmosphere-ocean feedback processes in the highly sensitive polar regions reflecting the critical role of sea ice in climate change

L'Ecuyer,T. and J.H. Jiang, 2010: Touring the Atmosphere Aboard the ATrain *Physics Today*, July 2010, featured article, pps.36-41

- A six year analysis of water budget components has been carried out for 10 global basins, with the focus on using remote sensing products. The analysis results in differential weighting of the products depending on their uncertainty and adjustments by the filter to close of the budget indicates the extent which components are adjusted to obtain closure. This provides the first multi-product budget time series with closure of the global water cycle, allowing for improved estimates that can be used for future diagnostic studies of climate variability.

Sheffield, Justin, Eric F. Wood, Francisco Munoz-Arriola, 2010 Long-term regional estimates of evapotranspiration for Mexico based on downscaled ISCCP data, *J Hydromet*.,; 11: 253-275, April 2010

- New algorithms merge CALIPSO, CloudSat, MODIS, and CERES data, computed heating rate, and produced a new combined data set. One year of merged data (from July 2006 through June 2007) are now available from Langley ASDC (http://eosweb.larc.nasa.gov/PRODOCS/ceres-news/table_ceres-news.html. Top-of-atmosphere and surface radiative flux (longwave) improvements provided by CALIPSO and CloudSat as well as cloud and aerosol properties are now available. New heating rate profiles with unprecedented vertical resolution and more accurate surface radiative flux have been used to estimate the uncertainty in the surface radiation budget, to determine aerosol and cloud radiative effects in the atmosphere, and in climate process sensitivity studies

Kato, S., S. Sum-Mack, W. F. Miller, F. G. Rose, Y. Chen, P. Minnis, and B. A. Wielicki (2010), Relation of among cloud occurrence frequency, overlap, and effective thickness derived from CALIPSO and CloudSat merged cloud vertical profiles, *J. Geophys. Res*., 115, D00H28, doi:10.1029/2009JD012277

- Global observations indicate that warming of surface temperature is not producing increase in global precipitation, but shifts noted with increase in deep tropics, decrease in middle latitudes. ENSO produces a similar small signal in global precipitation variations with regional variations,

while global volcano signal is more distinct. Links between components of the water cycle at various time and space scales important to understanding water and energy processes at various time scales and explaining similarities and differences. These documented variations will serve as benchmarks for reanalysis and improving climate models.

Adler, R.F., G. Gu, J.-J. Wang, G.J. Huffman, S. Curtis and D. Bolvin, 2008: Relationships between Global Precipitation and Surface Temperature on Inter-annual and Longer Time Scales (1979-2006). J. Geophys. Res., 113, D22104, doi:10.1029/2008JD010536.

Gu, G. and R. Adler, 2010. Precipitation and temperature variations on the inter-annual time scale: Assessing the impact of ENSO and volcanic eruptions. J. *Climate*

- Extensive error analyses for global surface radiative flux products including extensive international evaluation has demonstrated adequate accuracy for determining SW diffuse/direct flux ratio and the diurnal variations of the LW fluxes. It has been determined that the limiting accuracy of surface radiative fluxes now comes from aerosols in the shortwave, not clouds, and from surface temperatures in the longwave, not clouds. An important limitation of surface measured cloud parameters is the inhomogeneous diurnal sampling and the retrieval difficulties with broken clouds (SW) and cirrus clouds (LW). This is a significant step in understanding the role of cloud and aerosol radiation processes in climate.

Zhang, Y.-C., C.N. Long, W.B. Rossow, and E.G. Dutton, 2010: Exploiting diurnal variations to evaluate the ISCCP-FD flux calculations and radiative-flux-analysis-processed surface observations from BSRN, ARM and SURFRAD.*J. Geophys. Res*

- NEWS supported research provides the first independent assessment of the range (or uncertainty) in global ET estimates from remote sensing-driven models where the models were driven by common forcing data, based on EOS AQUA and TERRA sensor (MODIS, AIRS, CERES) data. Continued work using 1984-2008 ISCCP and SRB radiation data sets is on-going. This publication was listed one of the most downloaded paper from RSE from Jan – March

Vinukollu, Wood, Ferguson and Fisher (Global Estimates of Evapotranspiration for Climate Studies using Multi-Sensor Remote Sensing Data: Evaluation of Three Process-Based Approaches, *Remote Sens. Env*., 115(3), doi: 10.1016/j.rse.2010.11.006, 2010).

- The first global data set that quantifies the monthly distribution of surface water extent at ~25 km sampling intervals over 12 years has been produced from complementary multiple‐satellite observations. The variability of the surface water extent are compared with related variables such as in situ river discharges, altimeter-derived and in situ rivers/floodplains water level heights and precipitation estimates over inland water bodies and large river basins. In addition to a large seasonal and interannual variability, the new results show a slight overall decrease in global inundated area between 1993 and 2004. Land surface waters play a primary role in the global water cycle and climate. There is a widespread demand for accurate and long‐term quantitative

observations of their distribution over the whole globe. This new 12 year (1993–2004) data set of global surface water extent represents an unprecedented source of information for future hydrological or methane modeling.

Papa, F., C. Prigent, F. Aires, C. Jimenez, W. B. Rossow, and E. Matthews (2010), Interannual variability of surface water extent at the global scale, 1993-2004, J. Geophys. Res., 115, D12111, doi:10.1029/2009JD012674. Published 19 June

- The potential impact of anomalous cloud cover on the 2007 Arctic sea ice minimum was established using CloudSat and CALIPSO (A-Train) data. The results suggest that reduced cloud cover in 2007 may have significantly enhanced sea ice melt. The results highlight the importance of considering potential atmosphere-ocean feedback processes in the highly sensitive polar regions reflecting the critical role of sea ice in climate change.

Winker, D. M., J. Pelon, J. A. Coakley Jr., S. A. Ackerman, R. J. Charlson, P. R. Colarco, P. Flamant, A. Fu, R. M. Hoff, C. Kittaka, T. L. Kubar, H. Le Treut, M. P. Mccormick, G. Megie, L. Poole, K. Powell, C. Trepte, M. A. Vaughan, and B. A. Weilicki, The CALIPSO Mission, 2010: The CALIPSO Mission: A Global 3D View of Aerosols and Clouds. *AMS/BAMS*, September 2010, pp 1211 – 1229 (cited by 157)

- Ground water depletion using GRACE data: Rodell et al [2009] using GRACE data identified current rates of groundwater depletion in India. Famiglietti et al [2011] showed that California's major water source (the Sierra Nevada mountains) and America's fruit basket (California's Central Valley) were also experiencing significant rates of groundwater depletion. During the 2003-2010 time period studied, the combined Sacramento-San Joaquin River Basins lost the equivalent volume of Lake Mead in freshwater, nearly two-thirds of which came from groundwater. The work has resonated across the country, renewing calls for enhanced groundwater management, and garnering support for an accelerated GRACE follow-on mission. (The California paper has been worth its weight in gold -- congressional testimony, cited first as a justification for the GRACE-follow-on in the Climate Architecture document , NY Times story).
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Famiglietti, J. S., M. Lo, S. L. Ho, K. J. Anderson, J. Bethune, T. H. Syed, S. C. Swenson, C. R. de Linage and M. Rodell, 2011, Satellites Measure Recent Rates of Groundwater Depletion in California's Central Valley, *Geophys. Res. Lett*., 38, L03403, doi:10.1029/2010GL046442.

- This integrated, observational study improves our understanding of how inter-annual variations in the global hydrological cycle, specifically precipitation and tropospheric water vapor, depend on surface temperature changes, and how the ENSO and volcanic eruptions may modulate this dependence. Removal of the ENSO and volcano signals from the time series leaves evidence of large-scale temperature, vapor and precipitation inter-relations similar to those evident in global warming trends. This and following studies will provide better understanding of both inter-annual and climate-change variations in precipitation. *The Global Precipitation Climatology Project (GPCP) has successfully integrated recent SSMIS passive microwave data into the GPCP process to take over for the failed last calibrating SSMI satellite. This cross-calibration and extension of the*

highly used data set has allowed the GPCP to get back to near real time (April 2011). The GPCP analysis effort is headed by Adler/Huffman under NEWS support and is part of the WCRP/GEWEX international program.

Gu, G., and R. F. Adler, 2011: Large-scale, interannual relations among surface temperature, water vapor, and precipitation with and without ENSO and volcano forcings. *International Journal of Climatology*

- The International Satellite Cloud climatology Project (ISCCP) celebrated its 30 year anniversary in April 2013. ISCCP, the first project of the World Climate Research Program, organized by NASA, evolved as a multi-national, multi-agency cooperative effort to operate a multi-satellite global observing system and to perform a multi-data analysis to produce systematic and comprehensive cloud products. Over the course of its lifetime, ISCCP went beyond production of just cloud statistics to characterizing the associated properties of the atmosphere and surface that affect cloud processes and, together with cloud properties, affect Earth's radiation budget. Research achievements employing ISCCP and other satellite data products contributed to (1) the capability to determine the surface and in-atmosphere radiation budgets as well as the cloud effects on radiative fluxes at the surface, in atmosphere and at the top of atmosphere, (2) the beginning of the quantification of the relationships of cloud properties and precipitation, (3) the beginning of the characterization of different weather states from cloud property patterns and their associated radiative and latent heating amounts and atmospheric properties and dynamics, and (4) setting upper limits on the magnitude of the interannual variability of clouds. The conclusion of a major international cloud product assessment effort emphasized the generally good quantitative agreement among a dozen products concerning the basic cloud properties – amount, top temperature/pressure, optical thickness and particle size – and their latitudinal and seasonal variations.

http://www1.cuny.edu/mu/forum/2013/04/09/anniversary-conference-celebrates-30-years-of-cloud-research/

- Multiple global reanalysis and precipitation datasets were analyzed in order to explain the dynamic mechanisms that lead to an observed intensification of the monsoon trough and associated tropical cyclone activity over the Bay of Bengal (BOB) during the pre-monsoon month of May. We find that post-1979 increases in both pre-monsoon precipitation and tropical cyclone intensity are a result of enhanced large-scale monsoon circulation, characterized by lower-level cyclonic and upper-level anti-cyclonic anomalies. Such circulation anomalies are manifest of the tropospheric expansion that is caused by regional warming. The deepened monsoon trough in the BOB not only affects tropical cyclone frequency and timing, but also acts to direct more cyclones towards Myanmar. We propose that increasing sea surface temperature in the BOB has contributed to an increase in cyclone intensity. Our analyses of the Community Earth System Model single-forcing experiments suggest that tropospheric warming and a deepening of the monsoon trough can be explained by two discreet anthropogenic causes an increase in absorption due to aerosol loading, and an increase in the land-ocean thermal contrast that results from increased greenhouse gases. The ensuing circulation changes provide favorable conditions for tropical cyclones to grow and to track eastward towards Myanmar.(April 2013)

Wang, S.-Y., B. Buckley, J.-H. Yoon and B. Fosu. 2013: Intensification of pre-monsoon tropical cyclones in the Bay of Bengal and its impacts on Myanmar. *J. Geophysical Research*, doi: 10.1002/lrd.50396.

- The vertical distributions of cloud water content (CWC) and cloud fraction (CF) over the tropical oceans, produced by 13 coupled atmosphere-ocean models submitted to the Phase 5 of Coupled Model Intercomparison Project (CMIP5), are evaluated against CloudSat/CALIPSO observations as a function of large-scale parameters. Available

CALIPSO simulator CF outputs are also examined. A diagnostic framework is developed to decompose the cloud simulation errors into large-scale errors, cloud parameterization errors and covariation errors. We find that the cloud parameterization errors contribute predominantly to the total errors for all models. The errors associated with large-scale temperature and moisture structures are relatively greater than those associated with large-scale midtropospheric vertical velocity and lower-level divergence. All models capture the separation of deep and shallow clouds in distinct large-scale regimes; however, the vertical structures of high/low clouds and their variations with large-scale parameters differ significantly from the observations. The CWCs associated with deep convective clouds simulated in most models do not reach as high in altitude as observed, and their magnitudes are generally weaker than CloudSat total CWC, which includes the contribution of precipitating condensates, but are close to CloudSat nonprecipitating CWC. All models reproduce maximum CF associated with convective detrainment, but CALIPSO simulator CFs generally agree better with CloudSat/CALIPSO combined retrieval than the model CFs, especially in the midtroposphere. Model simulated low clouds tend to have little variation with large-scale parameters except lower-troposphere stability, while the observed low cloud CWC, CF, and cloud top height vary consistently in all large-scale regimes. (April 2013)

Su, H., J.H. Jiang, C. Zhai, V. Perun, J.T. Shen, A.D. Del Genio, L.S. Nazarenko, L.J. Donner, L.W. Horowitz, C.J. Seman, C.J. Morcrette, J. Petch, M.A. Ringer, J. Cole, M. dos Santos Mesquita, T. Iversen, J.E. Kristjansson, A. Gettelman, L.D. Rotstayn, S.J. Jeffrey, J.-L. Dufresne, M. Watanabe, H. Kawai, T. Koshiro, T. Wu, E.M. Volodin, T. L'Ecuyer, J. Teixeira, and G.L. Stephens, 2013: Diagnosis of regime-dependent cloud simulation errors in CMIP5 models using "A-Train" satellite observations and reanalysis data. *J. Geophys. Res.*, 118, 2762-2780, doi:10.1029/2012JD018575.

NEWS 10 year Publication Summary

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Aires, F., C. Prigent and W.B. Rossow, 2005: Sensitivity of Satellite Microwave and Infrared Observations to Soil Moisture at a Global Scale. II: Global Statistical Relationships. *J. Geophys. Res*., 110, doi 10.1029/2004JD005094. (cited by 16) http://www.agu.org/pubs/crossref/2005/2004JD005094.shtml

Jo, Y.-H., X.-H. Yan, B. Dzwonkowski, and W.T. Liu, 2005: A Study of Freshwater Discharge from the Amazon River into the Tropical Atlantic using Multi-Sensor Data. *Geophys. Res. Lett*., 32. L02605, doi:10.1029/2004GL021840. (cited by 7) http://airsea-www.jpl.nasa.gov/publication/paper/Jo-etal-2005.pdf

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Fetzer, E. J., B. H. Lambrigtsen, A. Eldering, H. H. Aumann, and M. T. Chahine 2006: Biases in Total Precipitable Water Vapor Climatologies from Atmospheric Infrared Sounder and Advanced Microwave Scanning Radiometer, *J. Geophys. Res*., 111, D09S16, (cited by 43) doi:10.1029/2005JD006598. http://trs-new.jpl.nasa.gov/dspace/bitstream/2014/40384/1/05-2351.pdf

Gettelman, A., E. J. Fetzer, A. Eldering and F. W. Irion 2006: The Global Distribution of Supersaturation in the Upper Troposphere from the Atmospheric Infrared Sounder, *J. Climate*, 23, 6089–6103. (cited by 66) http://www.cgd.ucar.edu/cms/andrew/papers/gettelman2006_ssatairs.pdf

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Press Release:

- Researchers Offer an Explanation for Expansion of Tropical Belts: A multi-decadal climate cycle is influencing the trend that expands deserts and pushes storm tracks closer to the poles

A team of researchers led by a former Scripps postdoctoral researcher offered a new explanation for why Earth's tropical belt, bounded by the tropics of Cancer and Capricorn, has progressively expanded since the late 1970s.

Robert J. Allen, now an assistant professor at the University of California, Riverside, led a NASA-funded study that found the recent widening of the tropical belt is primarily caused by multi-decadal sea surface temperature variability in the Pacific Ocean.

This variability includes the Pacific Decadal Oscillation (PDO), a pattern of Pacific climate variability that switches roughly every 30 years between two different circulation patterns in the North Pacific Ocean. The researchers say anthropogenic pollutants are another influence that modifies the PDO. The result is an expansion of the range of subtropical deserts that stay dry year-round tropical deserts and the pushing of storm tracks closer to the poles.

"It's great to see research that uses NASA data and models to unravel the workings of the climate system and help to decipher the differences between internal dynamics and possible influences of human activity, in this case aerosols," said Jared Entin, program manager of the NASA Energy and Water cycle Study, which funded the research. "The possibility to lead to any improvement in prediction of California precipitation is icing on the cake, because it would help

confront a well-known societal challenge."

Several explanations for the tropical belt widening have been proposed in recent years, such as radiative forcing due to greenhouse gas increase and stratospheric ozone depletion.

Prior analyses have found that climate models underestimate the observed rate of tropical widening, leading to questions on possible model deficiencies, possible errors in the observations, and lack of confidence in future projections," said Allen, an assistant professor of climatology in UC Riverside's Department of Earth Sciences, who led the study. "Furthermore, there has been no clear explanation for what is driving the widening."

Allen and colleagues including Scripps atmospheric science researcher Joel Norris found that the PDO is a more significant variable than previously realized.

Although this widening is considered a 'natural' mode of climate variability, we also show that anthropogenic pollutants have driven trends in the PDO," Allen said. "Thus, tropical widening is related to both the PDO and anthropogenic pollutants."